Carbon, Capture and Storage form Fossil Fuel and Biomass - Uses, Transportation, Cost and Potential Role in Stabilizing the Atmosphere

Akigwe, Ifeanyi M.

Enekwechi, K.E

Ejikeme, Ifeanyi

School of Engineering Technology, Federal Polytechnic,
Oko-Anambra State, Nigeria

Doi:10.5901/ajis.2013.v2n13p9

Abstract

The capture and storage of C02 from combustion of fossil fuels is gaining attraction as means to deal with climatic change. Co2 emissions from biomass convention processes can also be captured. If that is done, biomass energy with Co2, Capture and storage (BECS) would become a technology that removes Co2 from the atmosphere and at the same the same time deliver Co2 neutral energy carries (heat, electricity or hydrogen) to society. Here we present uses, transportation, cost and potential role of Co2 capture in stabilizing the atmosphere.

Keywords: *Carbon ($C0_2$) emission, climatic change, fossil fuel, biomass energy, carbon dioxide capture and storage (ccs)*

1. Introduction

Carbon Capture and Storage (CCS) is a process where Co_2 emitted from large stationary emission sources such as fossil fuel power plants or oil refineries, is captured and stored geologically in the underground.

Capturing Co_2: means separating it from the other components of the exhaust from a particular emission source. The exhaust may contain anything from three to almost 100percent Co_2, depending on the nature of the source. For instance, the exhaust from a typical coal power plant contains 12 to 15 percent $C0_2$. the rest is mostly nitrogen and some other gases and particles.

Storing Co_2, also known as Co_2 sequestration involves compressing the Co_2 at high pressure, making Co_2 become liquid and then transporting it by pipeline (or possibly ship of the storage site is far away) to a suitable location where it can be stored permanently. Unlike natural gas, Co_2 is not a flammable gas, so Co_2 transport is safer.

1.1 How is Co_2 Captured?

The Co_2 capture technologies are new to the power industry, they have been deployed for the past sixty (60) years by oil, gas and chemical industries. They are an integral component of natural gas processing and of many coal gasification processes used for the production of synthesis gas, chemicals and liquid fuels. There are three main $C0_2$ capture process for power generation.

i. Post-combustion
ii. post-combustion
iii. oxyfuel combustion

1.1.1 Post – combustion:

Capture involves separating the Co_2 from other exhaust gases after combustion of the fossil fuel. Post-Combustion Capture systems are similar to those that already remove pollutants such as particles, sulphur dioxides and nitrogen oxides from many power plants. The most commonly used process for post-combustion Co_2 capture is made possible through special chemicals called amines. A Co_2 rich gas stream, such as power plants fuel gas, is “bubbled” through an amine solution. The Co_2 bonds with the amines as it passes through the solution while other gas continue through the fuel. The Co_2 in the resulting Co_2 saturated amine solution is then removed from the amine “Captured” and is ready for carbon storage. The amines themselves can be recycle and re-used. Whilst post-combustion Co_2 capture is technically available for coal-based power plant. It has not yet been used commercially for large-scale Co_2 removal.

1.1.2 Pre-Combustion:

Capture involves separating Co_2 before the fuel is burnt. Solid or liquid fuels such as Coal, biomass or petroleum reaction at very high temperature with a controlled amount of oxygen. Gasification produces two gases, hydrogen and carbon monoxide (CO). The Co_2 is converted to Co_2 and removed, leaving pure hydrogen to burnt to produce electricity or used for another purpose. The Co_2 is then compressed into a supercritical fluid for transport and geological storage. The hydrogen can be used to generate power in an advance gas turbine and steam or in fuel cells or a combination of both.

1.1.3 Oxy fuel:

Combustion (also called oxy firing) involves the combustion of Coal in pure Oxygen, rather than air to fuel a conventional steam generator. By avoiding the introduction of nitrogen into the combustion chamber, the amount of Co_2 in the power station exhaust stream is greatly concentrated, making it easier to capture and compress. Oxy fuel combustion with Co_2 storage is currently at the demonstration stage.

1.1.4 List of international research projects

- Weyburn and great plains synfuels plant
- Sleipner field in the North Sea,coast of Norway
- The in salah gas plant Algeria
- Mit carbon carbon capture and sequestaration technologies program U.S.A
- Uk Ccs reduction research projects
- Cato 2, the Netherlands
- Solver red programme Germany

Carbon capture and storage from fossil fuels is by many seen as a key technological option to reduce Co_2 emissions (see e.g. Parson and Keith, 1998; World Energy Assessment, 2001; Williams, 2001). But it should be noted that the carbon releases from biomass conversion might also be captured and stored (Ishitani and Johansson (1996); Ekstrom et al. (1997); Williams (1998); Keith (2001); Azar et al. (2001); Mollersten and Yan (2001); Obersteiner et al.(2001); Keith and Rhodes (2002). If so, the biomass energy system would deliver Co_2 neutral energy carriers such as heat, electricity or hydrogen at the same time as it removes Co_2 from the atmosphere. We refer to this concept as Biomass Energy with Carbon Capture and Storage (BECS). If widely applied, the global energy system as a whole could become an instrument to remove Co_2 emission from the atmosphere on a continuous basis (as long as storage capacity is available). There are other ways of removing Co_2 from the atmosphere, e.g., through afforestation or direct capture from the air, but we have not included these options in this study.

In 1995, a total of 6.5 Billion tons of Carbon was released to the atmosphere as Co_2 . The current concentration of CO_2 in the atmosphere is about 360 per million (or 0.36 percent). This is 20percent higher than the level a centry ago, and it is projected to increase to over 700 parts per million (ppm) by the year2010.

1.2 Innovations/Inventions that will Reduce Energy Requirements.

1.2.1 Transportation:

A technology for Co_2 transportation and its environmental safety are well stabilized. Co_2 is largely inert in nature and easily handled and is already transported in high pressure pipelines. In the USA, Co_2 is already transported by pipeline for use in enhanced oil recovery (EOR) and Food industry. The means of transport depends on the quality of Co_2 to be transported, the terrain and the distance between the capture plant and storage site. In general, pipelines are used for large volumes over shorter distance. In some situations or locations, transport of Co_2 by ship may be more economical, particularly when the Co_2 has to be moved over large distance or overseas.

1.2.2 Geological Storage

Geological features being considered for Co_2 storage fall into categories;

- Deep saline formations
- Depleted oil and gas fields
- Unmineable coal seams.

As Co_2 is pumped deep underground, it is compressed by the higher pressures and becomes essentially a liquid. There are number of different types of geological trapping mechanism (depending on the physical and chemical characteristics of the rocks and fluid) which can be utilized for Co_2 storage.

1.2.3 Geological Trapping Mechanism

Structure storage: When the Co_2 is pumped underground, it is initially more buoyant than water and will rise up through the porous rocks until it reaches the top of the formation where it can become trapped by an impermeable layer of Cap-rocks, such as saline. The wells that were drilled to place the Co_2 in storage that can be scaled with plugs made of steel and cement.

1.2.4 Residual Storage:

Reservoir rocks act like a tight, rigid sponge. Air in a sponge is residually trapped and the sponge usually has to be squeezed several times to replace the air with water. When liquid Co_2 is pumped into a rock formation, much of it becomes stuck without the pore spaces of the rock and does not move.

1.2.5 Dissolution Storage:

Co_2 dissolves in salty water, just like sugar dissolves in tea. The water with Co_2 dissolved in it is even heavier than the water around it (without Co_2) and so sinks to the bottom of the rock formation.

1.2.6 Mineral Storage:

Co_2 dissolved in salt water is weakly acidic and can react with the minerals in the surrounding rocks, formatting new minerals, as coating on the rock (much like shellfish use calcium and carbon from seawater to form their shells). This process can be rapid or very slow

1.2.7 Deep Saline formations:

Are underground formations of permeable reservoir rock, such as sandstones, that are saturated with very salty water. (Which would never be used as drinking water) and covered by a layer of impermeable cap rock (e.g shale or clay) which acts as a seal. In case of gas and oil field, it was this cap rock that trapped the oil and gas underground for millions of years. Co_2 injected into the Cap rock and the ground water flow and in time, dissolves into the saline water formations is expected to take place at depths below 800m. saline aquifers have the largest storage potential globally but are the least well-explored and researched of the geological options. However, a number of storage are now using saline formations and have proven their viability and potential.

1.2.8 Depleted oil and gas fields:

Are well explored and geologically well-define and have proven ability to store hydrocarbons over geological time spans of millions of years. Co_2 is already widely used in the oil industry for enhanced oil Recovery (EOR) from mature oil filed it can mix with the crude oil causing it to swell and thereby reducing its viscosity, helping to maintain or increase the pressure in the reservoir. The combination of these processes allows more of the crude oil flow to the production wells.

1.2.9 Coal Seam:

Storage involves another form of trapping in which the injected Co_2 is adsorbed onto (accumulates on) the surface of the in situ coal in preference to other gases (such as methane) which are displayed. The effectiveness of the technique depends on the permeability of the coal seam. It is generally accepted that coal seam storage is most likely to be feasible when under taken in conjunction with enhanced coal bed methane recovery (ECBM) in which the commercial production of seam methane is assisted by the displacement effect of the Co_2

1.2.10 Mapping and monitoring:

Storage projects are carefully tracked through measurement, monitoring and verification (MM&V) procedures both during and after the period when the Co_2 is being injected. These procedures address the effectiveness and safety of storage activities and the behaviour of the injected Co_2 underground. MM&C are used to measure the amount of Co_2 stored at a specific geological site, to ensure the Co_2 is behaving as expected. The techniques used for MM&V are largely new applications of existing technologies. These technologies now monitor oil and gas field and waste storage sites. They measure injection rates and pressures, surface distribution of Co_2 injection well and local environmental impacts.

The IPCC found the risk of leaking from geological storage was very likely to be less than 1% over 100 years, and likely to be less than 1% over 1000 yrs.

1.2.11 Flue Gas:

This is the gas existing in the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven furnace, boiler or steam generator.

1.2.12 Sequestration:

Carbon sequestration is the capture of carbon dioxide (Co_2) from flue gases, such as on power plant station before stored in underground reservoirs.

2. Emerging Potentials/Uses for Co_2

2.1 Enhanced Oil recovery (EOR):

$C0_2$ is injected into depleted oil fields. The Co_2 acts as a solvent that reduces the viscosity of the oil, enabling it to flow to the production well. Once production is complete, Co_2 can potentially be permanently stored in the reservoir.

2.2 Urea Yield Boosting:

Most notable urea production, which globally produced and then consumed an estimated 113mt pa of Co_2. when natural gas is used as the feeds lock for urea production, surplus ammonia is usually produced. A number of projects have been implemented to capture Co_2 from ammonia reformer flue gas for injection into the urea production process. Captured Co_2 can be reacted with surplus ammonia to form urea. Urea is an example of solid nitrogen fertilizers

2.3 Oil and gas industry applications:

Co_2 is used as a fluid for the stimulation/ fracturing of oil and gas wells. It is typically trucked to site and injected as liquid carrying propping agents (sand and other materials which prop open the pores of the rock to prevent closure after stimulation).

2.4 Beverage Carbonation:

Carbonation of beverages with high-purity Co_2

2.5 Wine making:

Co_2 is used as a seal gas to prevent oxidation of the wine during maturation. Co_2 is also produce during the fermentation process, and it is already captured on-site for reuse for its inert gas properties.

2.6 Food Process preservation and packaging:

Co_2 is used for various applications in the food industry, including cooling while grinding powers such as spices and an insert atmosphere packing (MAP) with products such as cheese, poultry, snacks, produce and red meat, or in controlled atmosphere to prevent food spoilage in packaging application. Co_2 is modified atmosphere packaging (MAP) with products such as cheese, poultry, snacks, produce and red meat , or in controlled atmosphere packaging (CAP), where food products are products are packaged in an atmosphere designed to extend shelf-life carbon dioxide is commonly used in MAP and CAP because of its ability to inhibit growth of bacteria that cause spoilage.

2.7 Coffee decaffeination:

Superficial Co_2 is used as the solvent for decaffeinating coffee. It is preferred due to its inert and non-toxic properties.

2.8 Pharmaceutical processes:

Use of Co_2 in the pharmaceutical industry may overlap with other use identified, as it typically includes inserting, chemical synthesis and supercritical fluid extraction.

2.9 Horticulture:

Co_2 is provided to green house to maintain option Co_2 concentration and maximize plant growth rate. Sources include on-site cogeneration schemes as well as off-site industrial sources connected via pipeline networks.

2.10 Pulp and paper processing:

Co_2 is used to reduce pH during pulp wasting operations.

2.11 Water treatment:

Co_2 is used for re-mineralization of water following reverse osmosis and pH control (reduction).

2.12 Inserting:

Co_2 is used in a wide range of applications where the physical properties of an inert gas are desirable. This includes applications covered under other use categories such as welding shielding gas and gas used in food packaging and in wine production.

2.13 Steel Manufacture:

Co_2 is used in a minority of basic oxygen furnace as a bottom stirring agent. It is also used for dust suppression. Also in blast furnace, scraps are melted and reshaped, irons for molding machine parts, nails, etc and in other foundry projects.

2.14 Metal working:

Used for varied purposes, including chilling parts for shrink fitting, and hardening of sand cores and moulds.

2.15 Supercritical Co_2 as a solvent:

Co_2 is useful for high-pressure extraction and as a solvent to isolate targeted compounds, such as fragrances and favour Because of its low critical temperature and moderate pressure requirement, natural substances can be treated particularly gently. It is gaining favour as a solvent in the dry cleaning industry for this reason in niche applications, predominantly as a cleaning fluid.

2.16 Pneumatics:

Pneumatic applications for Co_2 include use as a portable power source for pneumatic hand tools and equipment, as well as a power source for pain ball guns and other recreational equipment.

2.17 Welding:

Used as a shrouding gas to prevent oxidation of the weld metal.

2.18 Refrigerant Gas:

$C0_2$ is used as the working fluid in refrigeration plant, particularly for large industrial air conditioning and refrigeration systems. It replaces more toxic refrigerant gases that also have much greater global warming potential.

2.19 Fire Suppression Technology:

When applied to a fire, Co_2 provides a heavy blanket of gas that reduces the oxygen level to a point where combustion cannot occur. Co_2 is used in fire extinguishers, as well as in industrial fire systems.

2.20 Enhanced Coal Bed methane Recovery (ECBM):

In Co_2 ECBM, Co_2 is injected into the coal, displacing and releasing adsorbed methane, which can be recovered at the surface

2.21 Enhanced geothermal system (EGS)-and Power Generation:

These are two ways in which superficial Co_2may be utilized in EGS geothermal power station/germination; firstly, it may be used as the circulating heat exchange fluid. The benefit here is that the significant density difference between the coal Co_2 flowing down the injection well(s) and hot Co_2 flowing up the production well (s) would eliminate the need for a circulation pump. Secondly, this concept could be extended, and the circulation Co_2 could also be used directed as the working fluid in a super critical Co_2 power. Supercritical Co_2 power cycles need not be limited to geothermal power plants, as the benefits of high efficiency and compact turbo machinery are not heat source-specific. The nuclear power industry is particularly interested in supercritical Co_2 power cycle for this reason.

2.22 Polymer Processing:

One example of Co_2 as a feed stock polymer processing involves the transformation of carbon dioxide into polycarbonates using proprietary zinc base catalyst system.

2.23 Chemical Synthesis:

(Excludes polymers and liquid fuels/hydrocarbons). Carbon and oxygen are both key elements in organic chemistry. Consequently, there are a wide range of chemicals that can at least theoretically utilize Co_2 as a feedstock for production, including organic acids, alcohols, esters and sugars. The partiality of $C0_2$ as a feedstock will vary significantly based on the current production routes. The dominant potential demand based n current markets, could come from acetic acid, which has a current global market of LMT Pa. Acetic acid can be produced by direct catalysis of Co_2 and methane

2.24 Algal bio-fixation:

The productive of algal cultivation systems can be increased significantly (up to a saturation point) by the injection/addition of Co_2 to the growth medium/solution.

2.25 Mineralization:

(Calcium carbonate and magnesium carbonate): Mildly (concentrated Co2 (eg. Power station flue gas) is contacted with mineral –loaded alkaline brine. The Co_2 present in the gas precipitates out as mineral carbonate (limestone/dolomite equivalent precipitates). The resulting product can be further processed to form an aggregate equivalent product for the construction industry, and can also potentially displace a small portion of Portland cementing concrete.

2.26 King soda (sodium Carbonate):

This is a variant of mineralization wherein Co_2 is contacted with sodium rich brine, resulting in the formation of sodium, bi-carbonate ($NaHCo_3$).

2.27 Co2 concrete curing:

This technology is focused on pre case concrete production facilities, where the waste Co_2 form in site flue gas permanently stored as un-reactive limestone within the concrete. This also limits the need for heats and steam in the curing process. The result is a reduction in emission of Co_2 equivalent, up to 12kg of ton (286 ibs Co_2 per Us ton) of per case concrete.

2.28 Bauxite residue treatment (red mud):

The extraction of aunina form bauxite ore result in a highly alkaline bauxite residue slurry known as" red" Mud" concentrated Co_2 can be injected into the red mud slurry to partially neutralize the product, improve its manageability, reducing its disposal costs and limiting its potential environmental impact .In the neutralization process, the Co_2 is converted to mineral form (typically carbonates). The resulting product remains slightly alkaline, and has potential as a soil amendment for acidic soils.

2.29 liquid fuels (Renewable method and formic acid):

Electrolysis of water produces H_2. The H_2 is combine with captured Co_2, compressed and reacted over a catalyst at moderate temperature and pressure 5mpa-225oc to produce methanol and water. Electro-reduction of Co_2 to produce formic acid (HCOOH) and O_2. Formic acid is the primary fuel. Formic acid has been classified as a liquid fuel as hydrogen is only released for the liquid formic acid as require.

3. Viability of the proposed projects

United Kingdom had played a major role in advocating for reduction of Co_2 emission and has strongly supported the deployment of CCS as part of a broader strategy to combat climate change/green house effects. Also the emerging uses of Co_2 world wide can be harnessed in Nigeria to generate about N10 billion Naira (yearly).

The market price of co_2 is in the range of $20 – 46 per tonne. The combined system of materials, Equipments and manpower can produce 20 to 50 tonnes of Co2 per day which will cost $ 920 per day, averaging $335, 800 (U.S. dollars) per annum. Other benefits accrue from blast furnace and charcoal Briquetting processes.

3.1 Materials and Equipment needed

1.	4 pcs Laptops (500G) with internet facilities	N500,000
2.	1 Pcs Printer	120,000
3.	photocopier/Scanner	450,000
4.	Paper work & Stationeries	100,000
5.	Officer equipment	100,000
6.	Blast furnace construction	7.0 million
7.	Generator 25KVA	4.5 million
8.	Change over for the blast furnace for C02 generation	2.0 million
9.	1 plot of land	3.5 million
10.	Centrifuge compressor to compress Co2	3.5 million
11.	Books/internet bills	300,000
12.	Construction of storage tank	3.2 million
13.	Oversea training at University of Nottingham U.K for two key personnel	5.0 million
	Total Cost	**30. 27 m**

3.2 Manpower requirement

S/N	Staff	Salary per year
1	1 Civil Engineer	1.5 million
2	1 Mechanical Engineer	1.5 million
3	1 Chemist	1.5 million
4	1 confidential Secretary	1.0 million
5	5 Unskilled Labour	500,000
	Total cost	**6,000,000**

Total project Cost of Manpower Requirement is = **N36.27M**

4. Risk Assessment

Numerical simulations on existing storage projects conclude that very long retention times are to be expected with geological storage. A study on the sleipner field concludes that no Co_2 would migrate into the North sea for 100 000 years, and that even after a million years, the annual rate of release would be only one millionth of the stored Co_2 (lindeberg and Bergbom, 2003). A study of the Forties Oilfield on the effects of uncertainties of in paramteters such as flow velocity in the aquifer and capillary entry pressure into the caprock, showed that less than 0,2% of the Co2 would escape into the overlying layers within 1000years, and even in the worst case, the maximum vertical distance moved by any of the Co_2 was less than halway to the seabed within this period (cawley et al,2005). Similarly, one study of the Weyburn storage site showed that within 5000 years there was 95% probability that less than 1% of the stored Co_2 would be released into the bisosphere (Walton et al., 2005) and another study of the same site found nor release to the atmosphere 5000 years at all (Zhou et al, 2005).

5. Conclusion and Recommendations

Carbon (iv) oxide or Co_2 capture was initiated by the Researchers to reduce the climatic problems associated with the accumulation of carbon (ii) oxide (carbon monoxide) in the atmosphere. This gives rise to a lot of people fainting on suffocation (or even death), ozone layer depletion and various green house effects.

These problems remained over the years in the country. However, carbon (iv) oxide (Co_2) 's potential and uses discussed in this paper will go a long way in development of oil and gas industries and cement production and steel producers which are the major revenue generation of the country and if harnessed properly in Nigeria will create Jobs for unemployed youths, aid oil and Gas industries and add value to the social well being of the populace.

Lastly, the Federal Government of Nigeria while trying to invest $4 billion dollars to finance a coal – fired power plant in Benue state come 2013 should utilize this technology to convert synthesis gas and $C0_2$ capture to methanol (blue fuel) which will become basis for a clean energy economy that actually reduce global warming by turning a potential green house gas, Co_2 into a global warming solution (fuel), etc.

References

Azar et al (2001), Targets for stabilization of atmospheric Co_2, Science 776,. Pp 1818-1819
Ekstrom et al (1997), Technologies and costs in Sweden for capture and storage of Co_2 from combination of fossil fuel for production of power and Heat, Stockholm, Sweden
IPCC (2005), Carbon dioxide capture and storage New York. NY Cambridge University press
Johnansson (1996), Capturing Co_2. IEA Greenhouse Gas R and D program me, Harvard University USA.
Keith and Rhode (2002), ''bury, burn or both . A two for one deal on biomass carbon and energy'', clim change 54 (3), 375-377
Mollersten and Yan (2001), Economic evaluation of biomass based energy systems with Co_2 capture and sequestration in kraft pulp mills, world resource, Rev l3 (4), 509-525
Obersteiner et cl (2001), ''Managing Climatic risk'' Science 294 (5543), pp 786 – 787.
Parson and Keith (1998), ''Fossil fuels without Co_2 emissions. Progress, prospects and policy implications'', Science 282, pp 1053 – 1054
Williams (2001), ''Towards zero emission from coal in china ,'' presented at U.S.A, china clean Energy forum Beijing(31 August)